Innovation paper for RC2024

Diagnostic system for **PUT**rain locomotive’s power train

1. Main goals of PUTrain project innovations

An integral process of rail vehicles exposition is controlling the wear parameters of drive system components. Subassemblies used in this system (i.e. traction motors, gears, wheelsets) due to the nature of which is performed should be monitored in a current manner [1]. This is particularly important from the point of view of entities providing transport services, because unforeseen damage that causes the vehicle to be excluded from active circulation directly generates costs due to unperformed transport work. Unwanted effects caused by the lack of continuous control of the condition of components used in rail vehicles are also felt by passengers and persons operating the vehicle. The answer to these issues is the field of technical diagnostics knowledge. The essence of this term is to assess the technical condition of machines and devices without disassembling them by examining the properties of their working and accompanying processes, which are related to the work of machine components [2].

This year the PUTrain team activities are aimed at monitoring residual processes in the form of vibration phenomena that are inherent in the work of machine components. Monitoring the operation of the drive system components using the proprietary diagnostic system will contribute to the optimization of replacement schedules and maintaining the efficiency of integral elements of the designed locomotive structure.

2. Advantages of Condition – Based Monitoring

The current approach to vehicle maintenance is mainly based on preventive or corrective measures. Top-down replacement schedules based on the calendar or working time of the object result in the non-use of the operational potential of individual elements used in machine components. The differences between Preventive and Condition-Based Maintenance are shown in figure 1.

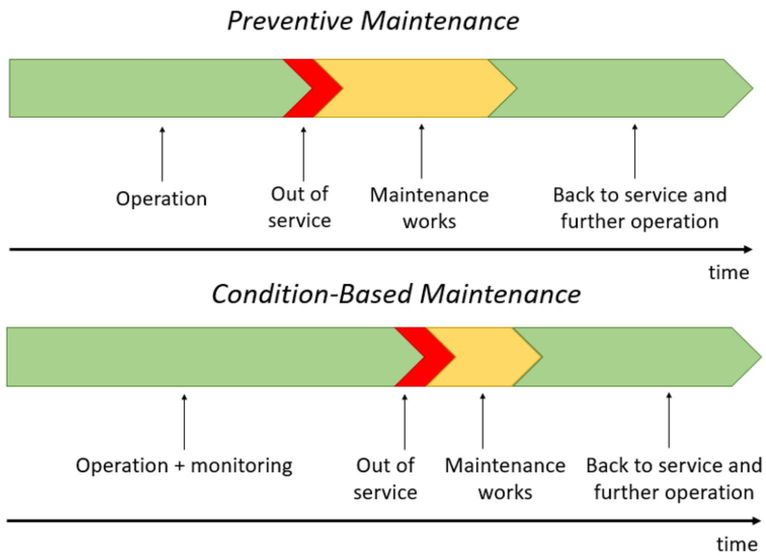

Figure 1 Comparison of Preventive and Condition – Based Maintenance

Predictive methods that include CBM are fundamentally different from those in the prevention group because they are based on the real state. Through ongoing monitoring of the machine condition, the initial symptoms of damage can be identified before they lead to the final shutdown of the machine from the continuity of operation. This approach leads to optimisation of availability, adjustment of exchange schedules and reduction of maintenance costs [3].

3. Technical aspects of PUTrain power train diagnostic system

Given the advantages of Condition – Based Maintenance, our team of engineers from Poznań University of Technology have decided to develop a dedicated power train diagnostic system for PUTrain locomotive which will participate in the Railway Challenge 2024. The functional diagram representing the hardware placement in the locomotive's body and main functionalities of the diagnostic system is shown in fig. 2.

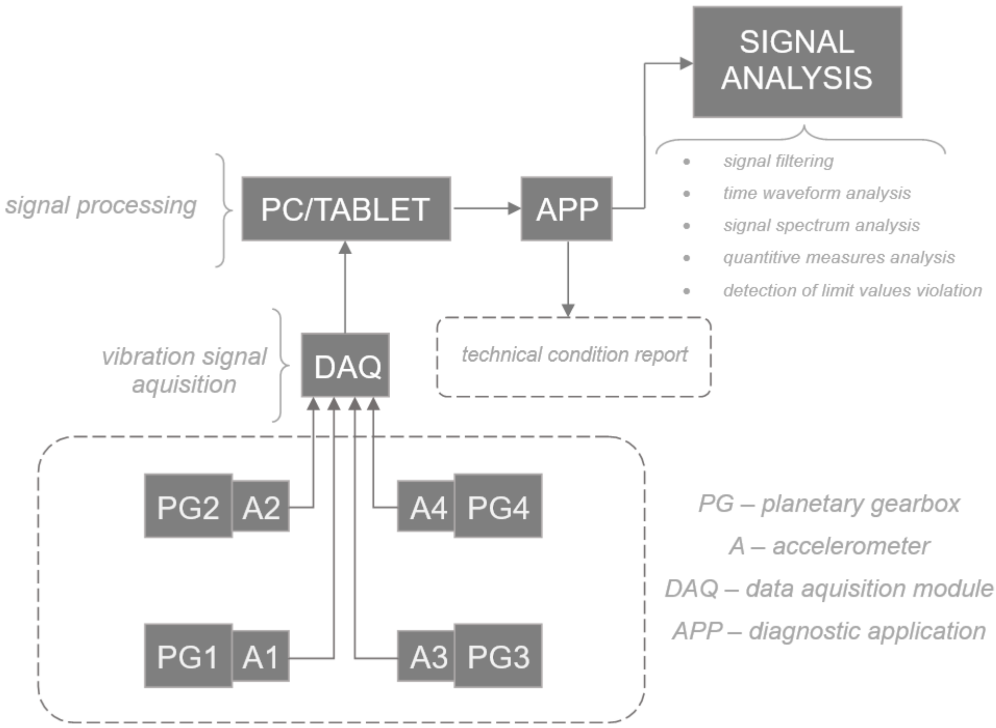

Figure 2 Functional diagram of PUTrain power train diagnostic system

The PUTrain locomotive powertrain diagnostic system can be divided into two interdependent layers: the hardware layer and the software layer. The hardware layer consists of four vibration acceleration transducers clip-mounted to the housing of each of the four planetary gearboxes, located at the output shaft of PMM traction motors.

The measuring apparatus used in the diagnostic system consists of single-axis piezoelectric transducers Bruel & Kjaer Type 4514-B-001 (fig. 3) that are characterised by reference sensitivity of 10 dB. The accelerometers used have a reference sensitivity of 10.01 mV/ms-2 and are capable of recording vibration signals in the frequency range of 1 Hz - 10kHz. The accelerometers are connected to the data acquisition module (DAQ) with the use of coaxial cables.

Figure 3 Bruel & Kjaer Type 4514-B-001 accelerometer [4]

Figure 4 National Instruments model USB-9612 [5]

The data acquisition module implemented in the diagnostic system is the National Instruments model USB-9162 data acquisition module (fig. 4).The data acquisition module is placed inside the central part of the locomotive body in a dedicated location. Each transducer is connected to one of the four available channels in the module.

Communication between the DAQ and the tablet is realised via an Ethernet to USB-A cable. The hardware layer is connected to the tablet with the diagnostic application installed which is designed for monitoring the technical condition of the PUTrain locomotive's power train during run.

The application was developed in the LabVIEW programming environment with the use of Sound And Vibration Toolkit. In the source code of the diagnostic application, there are several main modules to be distinguished. An important part of the code is the communication module between the application and the data acquisition module. It enables controlling the correct aggregation of information about the recorded vibration signals at each of the four measurement points. The described fragment of the code is connected with the function block responsible for storing information about the characteristics of the transducers and the determined sampling frequency.

Subsequent modules are responsible for processing the recorded signals and displaying diagnostic information obtained by using a particular signal analysis method. The function blocks in each module are designed to allow signals to be analysed conveniently in the application graphical user interface (GUI). Signals are filtered by the adaptive filter and several signal analyses may be performed. Time waveforms of signals, FFT and envelope spectra are displayed in GUI on a dedicated graph. The application is also embedded with a module whose task is to calculate the characteristic frequencies of planetary gears and rolling bearing components. The application also includes a module that carries out the task of determining the permissible and limiting values for three-stage evaluation of the technical condition and displaying information about the current vibration level and any exceedances at each of the established measurement points regarding values of calculated quantitative measures such as RMS value. Any violation of a set threshold is indicated via yellow or red diode on the screen. There is also a module for generating reports on the current diagnostic procedure and their export to an external file.

4. Conclusion

In summary, the PUTrain team proposed the introduction of the locomotive power train diagnostic system to provide high and efficient performance during maximised operation time. As proved in previous paragraphs such a system applied in this year locomotive should be the preferred solution for highly efficient, durable power trains in the railway industry. Condition – based monitoring methods provide excellent advantages such as prolonging the exploitation time of powertrain components or reduced maintenance and logistics costs.

New attitudes towards the maintenance of rail vehicles may encourage carriers to apply diagnostic systems in order to improve many aspects of railways. Railway undertakings should gradually implement new solutions to improve passenger comfort and safety. Presented idea aims to make the construction of locomotives more environmentally friendly and improve the maintenance strategy as well as the efficiency of rail vehicles.

5. References

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